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N64-16012
CODE-1
CR-55168

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OTS PRICE

XEROX $ 1.60 ph

MICROFILM $ 0.80 mf.

Alkaline Battery Division

GULTON INDUSTRIES, INC.

Metuchen, N. J.

(NASA CR ----) OTS:

DESIGN, DEVELOPMENT AND MANUFACTURE OF
STORAGE BATTERIES FOR FUTURE SATELLITES

REPORT NO. 1

National Aeronautics and Space Administration (NASA) Contract No. NAS5-509

First Quarterly Progress Report

4 Nov. 1960 to 4 Feb. 1961

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1096924

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TABLE OF CONTENTS

		Page
I.	ABSTRACT	Ia
II.	FABRICATION OF 30 CELLS (PHASE I)	1
III.	ESTABLISHMENT OF A PILOT LINE FOR FABRICATION OF HERMETICALLY-SEALED CELLS (PHASE II)	4
	A. CELL ASSEMBLY LINE	4
	B. ELECTRODE PROCESSING LINE	7
IV.	CONCLUSIONS	8
V.	PROGRAM FOR NEXT PERIOD	9
VI.	ALLOCATION OF FUNDS	10
VII.	FIGURES	11

I. ABSTRACT

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The difficulties and problems involved in producing reliable sealed cells on a semi-production basis have become evident, and considerable engineering effort has been devoted to overcoming these difficulties. auth.

Several modifications in the seal and cover design have been made so that the heat encountered in joining the cover to the can does not injure the hermetic seal.

Electrode stocks embodying the desirable features of the VO-5HS and incorporating the new separator have been assembled. Individual plates have been checked on a weight basis, after electrical formation, in order to improve uniformity between cells.

Details have been worked out for the cell assembly line portion of the pilot line for the fabrication of hermetically-sealed cells. The required equipment and facilities are being purchased and built.

Design and specification of equipment for the electrode processing line has been started. Procurement of a small, continuous sintering furnace is in progress. For what use?

[illegible]

AUTHOR

II. FABRICATION OF 30 CELLS (PHASE I)

The problems and difficulties involved in producing reliable sealed cells on a semi-production basis have become evident and have been the subject of considerable engineering effort during the past three months. The electrochemical and electrical characteristics of the VO 5-HS cell have been well established, and testing of laboratory prototypes (sealed by gasketing techniques) has continued while techniques are being established to reliably assemble the hermetically-sealed cell package. The overcharge voltage and pressure characteristics have previously been submitted but are included again as Figures 1 and 2, for reference. Figure 3 indicates cycle performance in a 30% depth of cycle which, at this writing, is at the 1050 cycle point with no apparent deterioration of cell performance. No shorting of cells due to separator failure has been experienced.

How many samples?

The size of the cell being produced determines several conditions which affect the ceramic-to-metal seal. If the cell is small, for example, the VO-5HS cell, the proximity of the various seals and connections imposes considerable stress upon the ceramic seal, if high temperatures are used in making these seals and connections. Owing to the necessity for compactness in cells for satellite applications, the height of a cell and, therefore, the terminal must be kept at a minimum. This means that the ceramic-to-metal seal is in close proximity to the point where the plates connect to the terminal. Since the number of plates in the VO-5HS cell is only 19, the length of the cell is small; and therefore, the joint between the cover and the container is in close proximity to the seal.

As the cell was originally conceived, the terminal and comb were one piece, using what was essentially a modification of existing hardware for another type cell. The terminal was sealed into a cover, checked for leakage; and then, plates were installed by heliarcing the tabs to the terminal comb. In a great many cases, the heat of welding into the heavy section of the comb proved too much for the seal to tolerate; and the seal broke down. Equipment available at this time for checking the seals was not adaptable to checking the seal with the plates installed; so, the cause for the loss of a great many seals was obscured by other operations which were completed before the seal could again be checked. Eventual recognition of the problem lead first to a modification of the terminal to a two-piece construction of a much smaller section between any welds and the seal. By making the comb separate from the terminal stud, the weld of the plates to the comb could be improved, giving a more rigid structure and a better electrical connection. It was then intended to join the comb to the stud by a quick pass of the heliarc; but this again proved too much for the seal, since the confines of the cell were making the weld still too close to the seal. Another modification of the terminal

How about induction welding

was undertaken to provide for spotwelding of the comb to the stud. This method permits very localized heating, with the welder electrodes acting as heat sinks. This last configuration is currently being used. Sounds like a compromise design

The joining of the cover to the cell container provided another source of trouble for the seal. Again, the problem stemmed from a weld too close to the seal. Three possible solutions presented themselves: (1) Remove the weld to a more distant location from the seal, (2) Use a lower temperature method of joining the cover to the container, (3) Divorce the seal from the cover while the cover to container joint is being made and then join the terminal to the cover by a lower temperature means. Since the only direction the weld could be moved is upward at a cost of enlarging the cell and the terminal with attendant increases in weight, Method (1) has been eliminated. Corrosion tests of alloys suitable for making the container joints at lower temperatures have indicated that a cadmium solder would be suitable; and this method, (2), is currently being used. The use of the cadmium solder also makes Method (3) feasible, and this method is also being tried. How good is this method?

It should be noted that changes in design have caused considerable lost time in procurement of parts. Metal terminal parts may be obtained in approximately 1 week; cover changes take longer. The procurement of ceramics requires 4 to 6 weeks. To avoid too great a delay in the procurement of ceramics, we have been obtaining green ceramic of material found to be satisfactory and machining and firing our own parts.

Another factor in the production of ceramic-to-metal seals is the furnace used to make the actual bond. High-vacuum equipment is necessary, which means the material is being heated by radiation only. It is extremely difficult to obtain even heat at more than one seal at a time, since the furnace heating element is not perfectly uniform, and the parts being sealed tend to shadow one another, with the result that one seal may flow too far while waiting for another to flow enough. Weight! [illegible]

The furnace initially selected for the job is a versatile machine and is fine for laboratory production where flexibility is required; but it has one great drawback, in that the heating coils are in the vacuum and are subject to plating by any of the sealing alloy which is vaporized while waiting for the metal to flow. The result is that coils become shunted after relatively few firings, and the heat distribution in the furnace is further upset. A solution to this problem would be a furnace having coils external to the vacuum area and a cooling chamber into which the work could be moved to speed the process.

Testing of the ceramic-to-metal seal is being conducted at several stages in the manufacture of the cell. A mass spectrometer detecting helium leakage is the apparatus used to conduct the tests. The seals are first checked individually upon removal from the furnace. Another check is made when the plates have been joined to the terminals. A third test is conducted upon the cell after the cover has been joined to the container, but before electrolyte is added to the cell. A final test is to be made after the cells are tested electrically and the pinch tube sealed. This final test may be conducted in two manners: first, helium may be introduced to the cell before the final pinch is made and, second, the cell may be exposed to a high-pressure helium atmosphere and checked for any traces which leak in and then back out. The former method is the surest method.

The cell electrode assemblies for Phase I are being assembled, using materials currently available and existing techniques and equipment. Gulton production type plates are formed in groups equivalent to a cell pack: that is, 9 positive plates, with 10 negative plates. Four complete cycles are applied to the plates as follows:

Cycle 1. - Charge at C/6.7 for 16 hrs.; discharge at C/1.67 for 2 hrs.

Cycles 2-4.- Charge at C/4.16 for 6 hrs.; discharge at C/1.67 for 2 hrs. On completion of the last cycle, the cells are shorted to 0 volts; the plates are removed, washed, dried; and then, all the plates are weighed. The plates are separated into groups in increments of 0.1 gram. Plates are then matched according to their formed weight, to assemble cell packs. When the pilot line of Phase II goes into partial operation, the plates will be matched according to electrical characteristics. (Good)

* Exact definition of C?

What correlation is there between formed weight and [illegible]?

Why is weight rather than electrical characteristics [illegible] criterion?

III. ESTABLISHMENT OF A PILOT LINE FOR FABRICATION OF HERMETICALLY-SEALED CELLS (PHASE II)

An area of approximately 1,500 square feet has been allocated in the new building of the Alkaline Battery Division of Gulton Industries, Inc., for the establishment of pilot production facilities. This area will be broken down into two separate rooms, one of which will be air conditioned for final assembly of aerospace cells, the other containing the process equipment for plate manufacture.

A. CELL ASSEMBLY LINE

The final assembly line will be the first portion of the plant to be put into operation. Figure 4 shows schematically the flow of material through this portion of the plant. There are 9 inspection operations in this line, five of which deal with the continuity of the seal. The remaining four inspections concern the electrical operation of the cell.

The first inspection is designed to insure that the plates are physically sound and within tolerance on thickness. The second inspection, made on the last discharge of the formation cycles, determines the electrical characteristics of each plate, so that plates may be matched to obtain uniform cells.

Figure 5 shows the circuit used on the first cycles of the formation. The plates are transferred from this circuit to the circuit of Figure 6, which is basically a Schmidt Trigger which is set to stop the discharge of a pair of plates at a predetermined voltage and then stop a timer, so that the capacity of the plates may be determined.

The third inspection removes any plates which have shown signs of physical deterioration during formation. The acceptable plates are then processed into cells, and a final test of electrical characteristics is made before the pinch tube is finally sealed. For this final test, pressure gauges are installed, so that any tendency toward excessive pressure may be detected and uniformity of the negative plates may be checked.

At various points in the assembly, the seals are tested with a Vecco mass spectrometer. A machine of this nature provides the best possible check on leakage in a short time. The first three leak checks remove any elements from final assembly at points where repairs may be effected or at least before considerable additional time is expended in trying to make complete cells. This also permits fatality rates to be checked according to operations and corrective measures instituted where needed.

Inspected plates are coated along the edges with either polymethacrylate in methyl ethyl ketone or polystyrene in a solvent of 50-50 methyl ethyl ketone and toluene. The latter solution appears better from the standpoint of the insulation provided and resistance to potassium hydroxide. The coated plates are then passed to the tank formation station where they are cycled on the basic circuit shown on Figure 5. This circuit is arranged so that the pairs of plates may be placed in a common electrolyte tank, in a parallel arrangement. After a predetermined length of time on discharge, at the end of the fourth cycle, the plates are transferred to the circuit of Figure 6, where the final discharge is timed and automatically stopped at 1 volt. Plates are then selected according to the length of time it takes to reach the cut-off voltage.

Following selection, the plates are washed free of potassium hydroxide, oven dried, and stored in a clean, dry receptacle, to prevent contamination of plates. From this point until the cells are filled with electrolyte, all precautions are taken to insure that the plates are dry and uncontaminated. Human perspiration and skin oils are contaminants which are to be avoided wherever possible.

All steps involved in assembling the electrode pack have to be made with proper fixtures, jigs, and heat sinks. Location of the electrode components is very important to the subsequent assembly of the cell and greatly effects the ease with which the cover may be joined to the container.

After the cells are assembled and checked for leaks, they are evacuated and filled with electrolyte. The reason for evacuation at this point is to make it easier to introduce the electrolyte and to avoid carbonate contamination in the cell. After introduction of electrolyte, an inert gas back fill is used to prevent contamination by air while a valve and pressure gauge are installed. Following installation of the gauge, the gas is evacuated from the cell, leaving essentially a water vapor atmosphere within.

At this stage, the cell will be ready to go on electrical test, for which an automatic cycling panel is being designed. Following the electrical testing of the cell, a trace of helium is introduced into the cell for leak detection, the pinch tube closed and soldered, and then a final test for leaks is conducted prior to further disposition of the cell.

The equipment being used to make the ceramic-to-metal seal is a Kinney High Vacuum pumping unit and a Kinney power supply. The furnace proper is a coil of molybdenum strip wound within a ceramic tube. This arrangement has proved to be quite flexible for laboratory production of seals; but it does have some drawbacks, in that the ceramic tube eventually becomes silvered and shorts out turns of the coil, giving very uneven heat. For the present, it is anticipated that this furnace will continue to be used in the pilot plant until such time as production warrants the purchase of a unit more adaptable for production operation.

Heliarc welding equipment is used to connect the electrodes to the combs. This same equipment may also be used to weld covers to containers as the process for making this joint is further developed. Gas torch equipment is also available for making these joints with low melting alloys and for joining seals of the floating configuration to covers with these same alloys. Spotwelding equipment is also available for joining combs to terminals where it is necessary to keep excessive heat from reaching the ceramic-to-metal seal.

B. ELECTRODE PROCESSING LINE

Design and specification of equipment for the electrode processing line have been started. The first item being considered, since it is a major item requiring long delivery time, is the sintering furnace.

The sintering furnace will be of the continuous strip variety handling strip up to 8 inches wide. This should provide more than enough capacity to feed the facilities of the rest of the pilot operation. At this time, two proposals are being considered to determine which would provide the most economical furnace to get the desired results.

Vacuum impregnation of the active material into the sintered plate is anticipated as the method which will be used first in the pilot plant. This method has been well tried and proved reliable. A new impregnation method is under development in our laboratories, utilizing a low-surface tension principle. Indications to date are that this method can result in an increase in watt hour per pound output of about 10%. The method is also very adaptable to our pilot plant since it could be placed directly in the line with the sintering furnace to impregnate strip continuously, eliminating much handling, and completing the impregnation in fewer cycles.

The eventual aim in this process plant is the production of plates in such a manner that no operator need touch the plate or adjust the process between the time raw material is fed in at one end of the line and finished plates come out the other. This will make for much more uniform plates and greater reliability for aerospace applications.

IV. CONCLUSIONS

A. FABRICATION OF CELLS

The basic mechanism for making a reliable ceramic-to-metal seal is now understood. This is the most critical point in the manufacture of a hermetically-sealed cell. The other difficulties in closing the cell may be solved by design modifications in the cell. Three basic approaches to the problems have been outlined in this report. These approaches, as well as all others which become evident, will be thoroughly investigated, in order that the best possible hermetically-sealed cell may be produced.

B. ESTABLISHMENT OF A PILOT LINE

The steps involved in the production of reliable hermetically-sealed cells have been thoroughly studied. It is believed that a pilot production line has been outlined which will give reliability in the cell while maintaining a flexibility so that various designs and sizes of cell may be produced.

7. PROGRAM FOR NEXT PERIOD

A. FABRICATION OF CELLS

It is expected that delivery of the first cells will begin during the month of March, 1961. These cells are being manufactured on a laboratory line, utilizing existing hardware as much as is possible.

B. ESTABLISHMENT OF A PILOT LINE FOR FABRICATION OF HERMETICALLY-SEALED CELLS

Within the next month, we expect to move our entire operation (laboratory, pilot production, and offices) to our new building. The equipment now available for the pilot plant will be installed and placed in operation as needed, while the balance of the design and construction of the plant continues.

The first items to be given consideration in design and fabrication will be:

(1) Formation apparatus

(2) Washing and drying facilities

(3) Helium Leak detection apparatus

(4) Cell cycling apparatus

(5) Sintering furnace

Actual construction of the plant facility and installation of equipment will begin as soon as we can occupy the building and as rapidly as equipment can be obtained.

VI. ALLOCATION OF FUNDS

A. PERSONNEL

	hours
R. C. Shair - Director of Research	48
R. Dagnall - Project Engineer	247
T. Staub - Mechanical Engineer	176
A. Cherdak - Electrical Engineer	16
J. Alfieri - Junior Engineer	329
R. Waldorf - Junior Engineer	34
D. Mowen - Junior Engineer	96
L. Andrews - Junior Engineer	19
Assembly welding and shop labor	922
	1,887

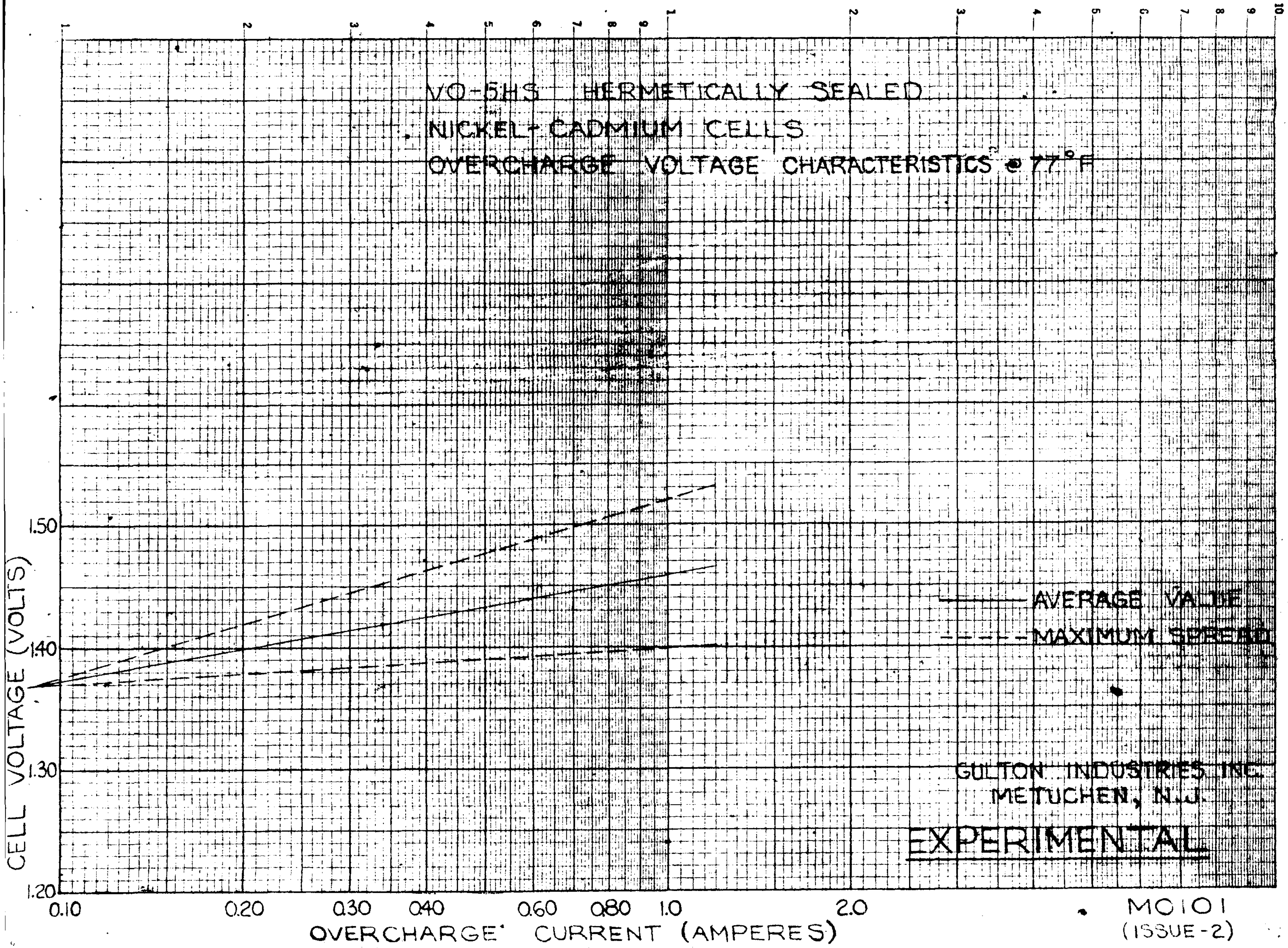
Direct Labor Cost $5,022

B. MATERIAL AND EQUIPMENT

Material Cost $10,552

C. TOTAL COST TO DATE

(Material, Labor, Overhead, G&A) $28,883 TOTAL



MC101
(ISSUE-2)

FIGURE 1

K+E 10 X 10 TO THE INCH 359-5DG KEUFFEL & ESSER CO. MADE IN U.S.A.

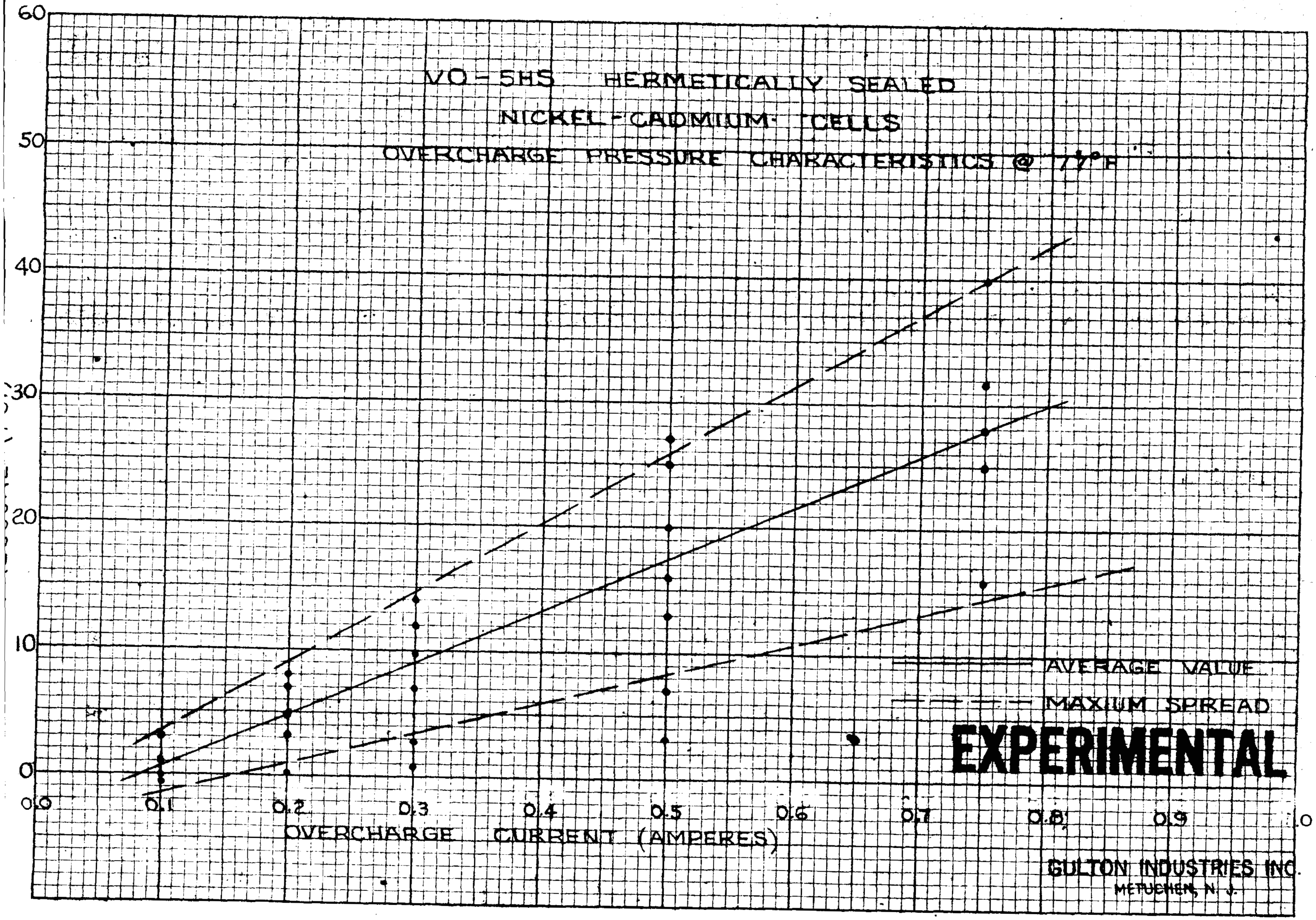


FIGURE 2

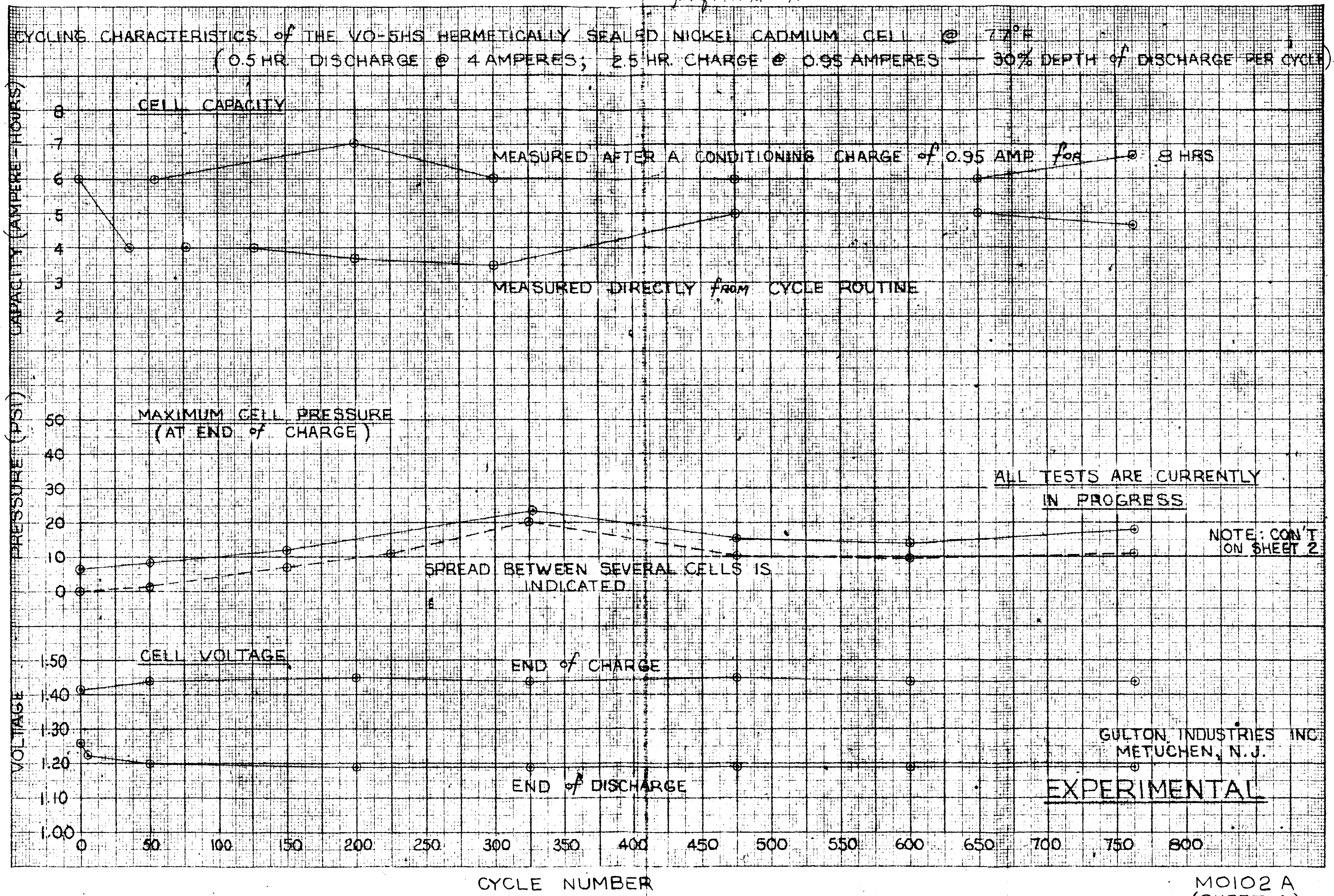
MO111

FIGURE 3A

Ieff = 89% peff = 71%
Veff = 88%

8.5 hr rate
equiv of 14% for 30/60 arbd

19% overcharge/cycle



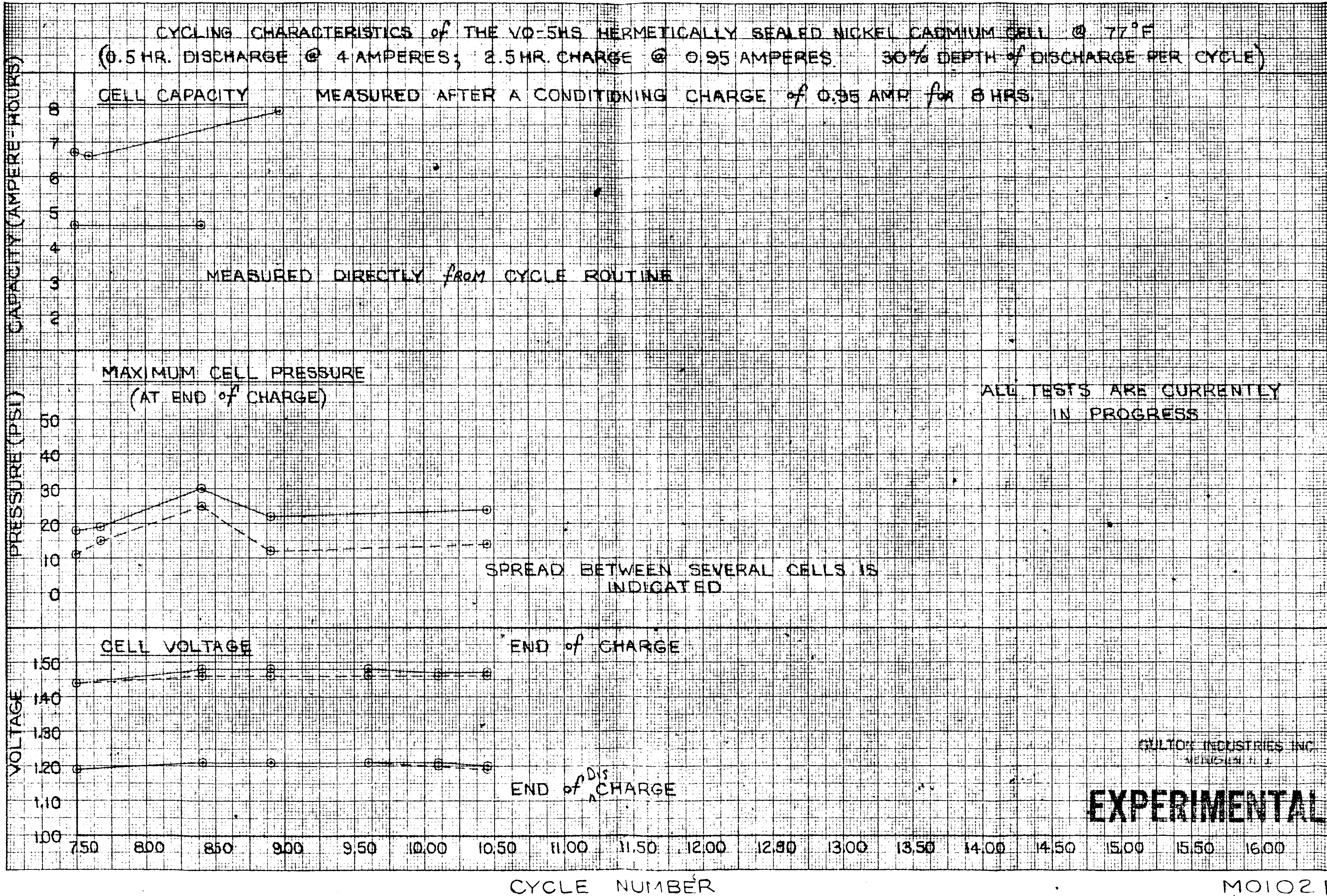
6.7
Nom.
Based on
30%

+10%

10 X 10 TO THE CM. 359-14L
KEUFFEL & ESSER CO. MADE IN U.S.A.

MO102 A
(SHEET 1)

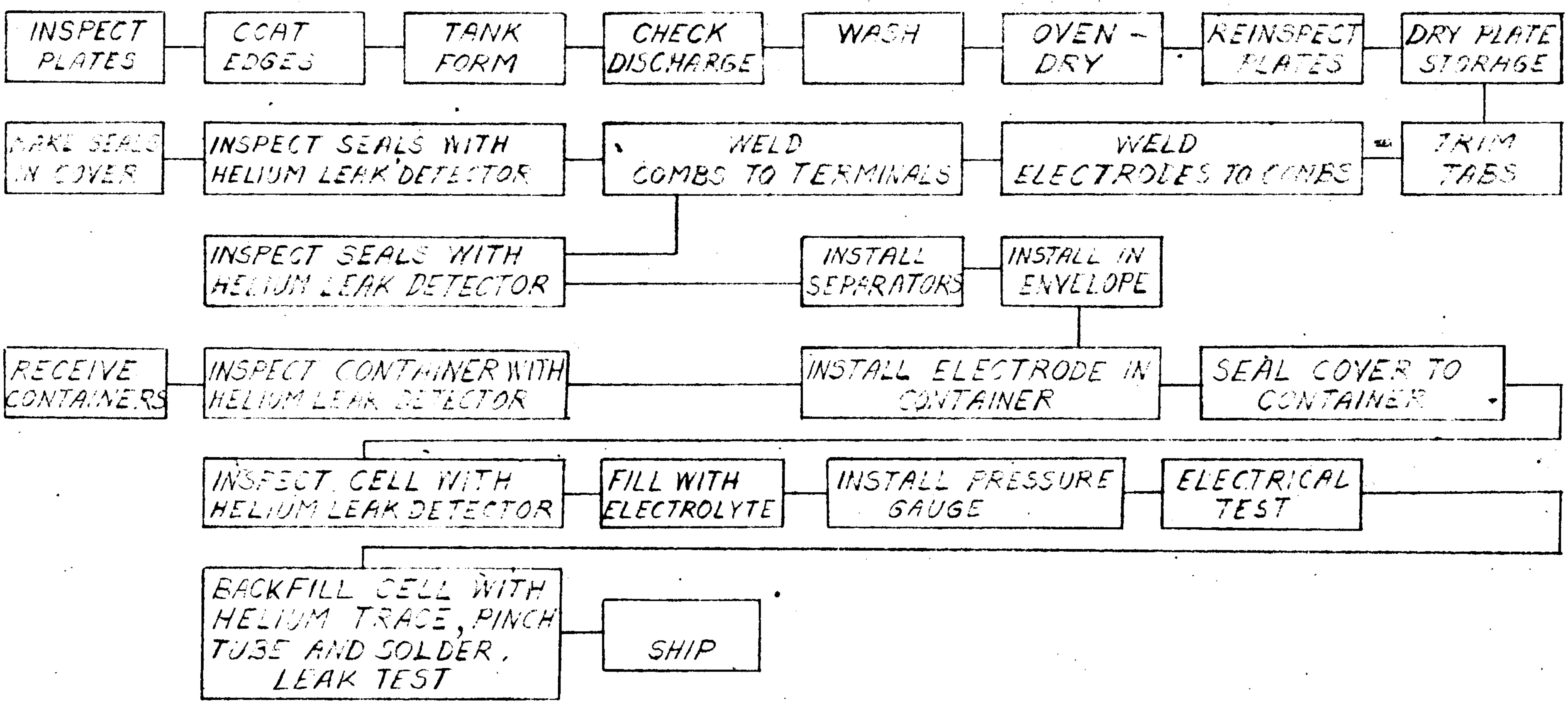
FIGURE 3A



M0102 B
(SHEET 2)

K+E 10 X 10 TO THE CM. 359-14L
KEUFFEL & ESSER CO. MADE IN U.S.A.

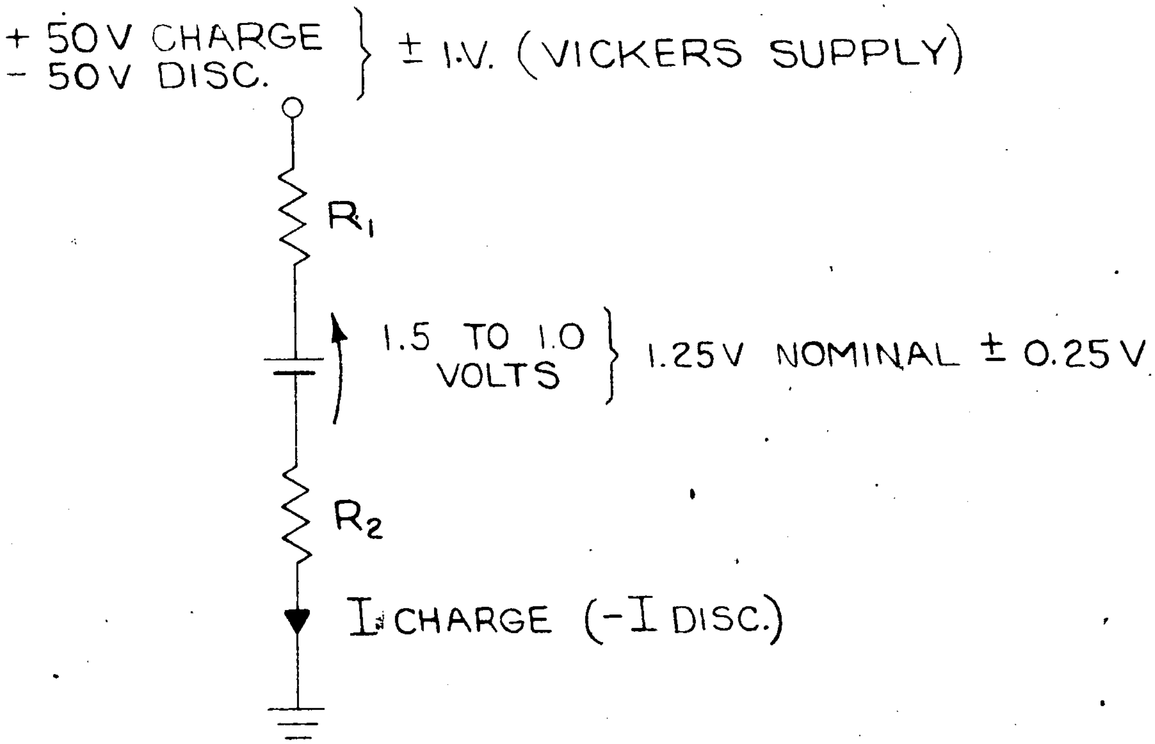
FIGURE 4 ASSEMBLY PLANT FLOW CHART



M0177

FIGURE 5

CELL FORMATION CIRCUIT for CYCLES 1, 2 & 3

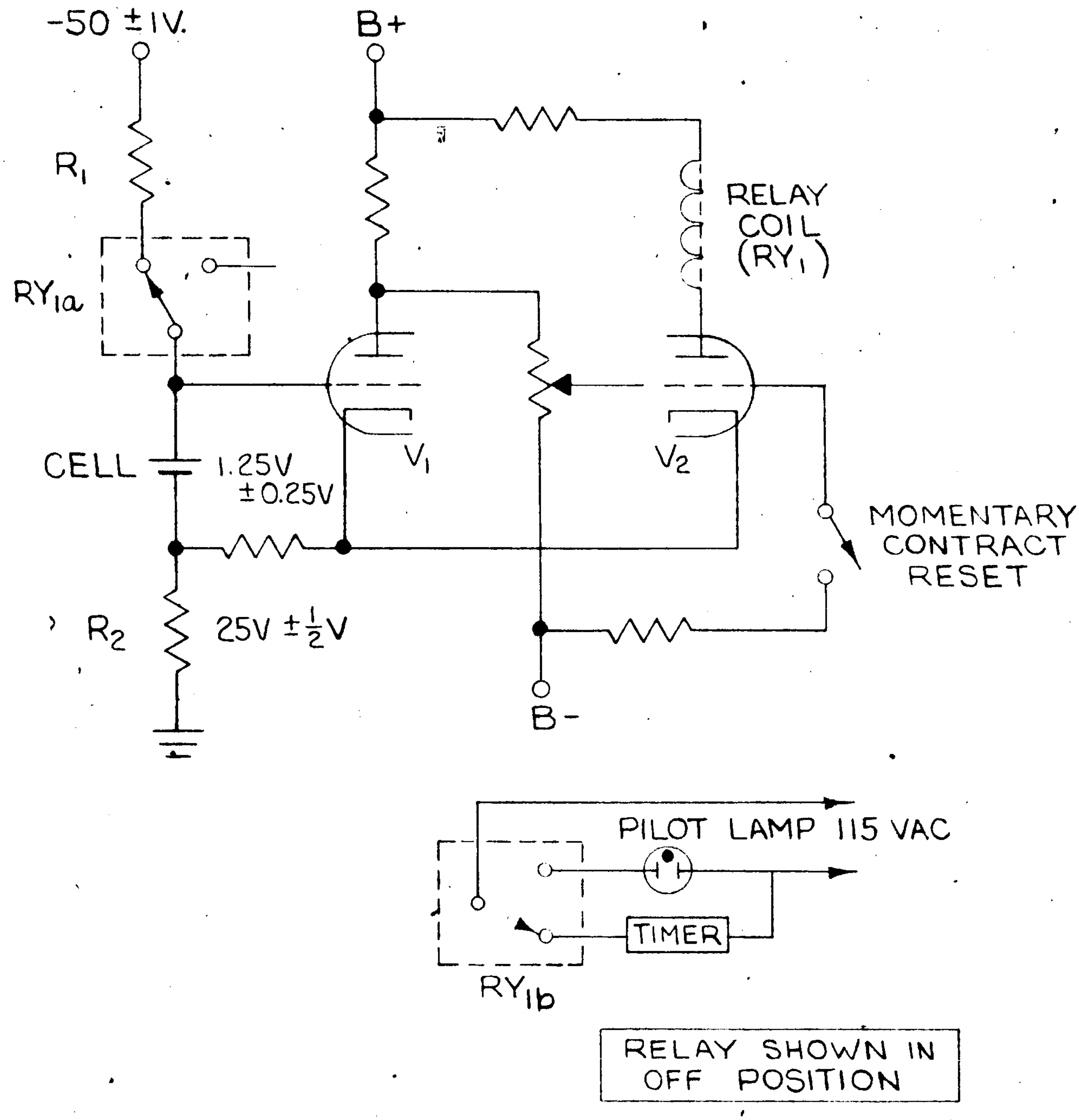


$$I_{\text{CHARGE}}\ (-I_{\text{DISC.}}) = \frac{50-1.25}{R_1+R_2} \pm \frac{1.25}{R_1+R_2}$$

M0175

FIGURE 6

CELL FORMATION & CAPACITY DETERMINATION CIRCUIT for 4th CYCLE DISCHARGE



M0176